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(54) Electrostatic chuck.

(57) A split-ring electrostatic chuck (10) comprising: a substantially disc-shaped first electrode (12) having a raised central hub portion (12a) and a raised outer rim portion (12b); a second electrode (14) having a donut shape with a substantially circular wall (16) defining a central opening (18) and an outer edge (24), said hub (12a) of said first electrode engaging said central opening (18) of said second electrode (14) and said rim (12b) of said first electrode (12) surrounding said outer edge (24) of said second electrode (14); an insulator (28) electrically separating said first electrode (12) from said second electrode (14) and covering the tops (26) of said first electrode and said second electrode to form a clamping surface; a first electrical contact (46) connected to said first electrode (12); and a second electrical contact (48) connected to said second electrode (14), wherein a voltage is applied between said first electrode and said second electrode generating an attractive force for clamping a wafer to said clamping surface (26).

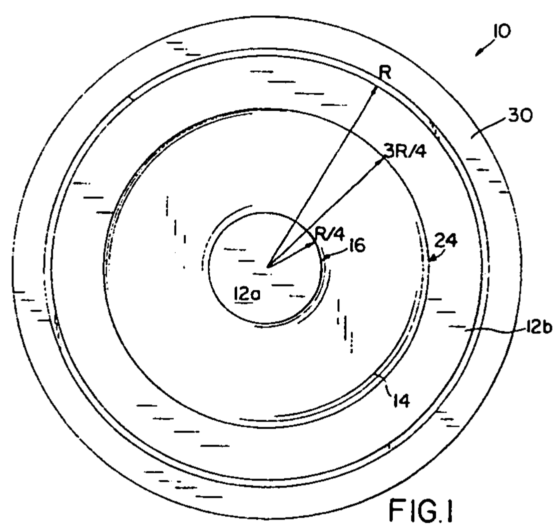

FIG.1

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The present invention relates, in general, to an electrostatic chuck for holding semiconductor wafers, especially silicon wafers, and to a method for fabricating such a device. More particularly, the present invention relates to a split-electrode electrostatic chuck in which electrical contact to the wafer is not required and to a sequence of operations used to manufacture that chuck.

In the manufacture of semiconductor devices, care must be taken when processing the semiconductor wafer. Processing treatments may involve directing charged particles toward the wafer. For example, selected areas of the wafer can have their conductivity type modified by implanting ions. As another example, wafers formed of such materials as Si, SiO_2, Si_3N_4,Al, W, No, Ti and the alloys of these metals and the like may be dry etched using a plasma etch, a sputter etch, or a reactive sputter etch.

Unfortunately, processing treatments involving the use of beams of charged particles generate thermal energy in the wafer. The problems caused by such thermal energy include expansion and local distortion of the wafer and, in the case of a plasma etch, for example, melting of the resist used for the mask. In order to avoid these problems, the heat generated must be dissipated quickly. Additional processing problems are created because the wafers usually are not perfectly flat; they have warps with lengths on the order of a few micrometers.

As is known in the art, improved processing of wafers can be achieved if the wafer is clamped substantially flat against a support base which is temperature controlled during treatment. By clamping the wafer, the number of points of contact between the wafer and the support is increased; therefore, the thermal conductivity between the wafer and support is enhanced, warps are corrected, and the contact area is extended. The improved heat transfer, whether to or from the wafer, enables better control of the temperature of the wafer and, hence, better process control.

Accordingly, a variety of chucks have been proposed to clamp the wafer during processing. Such chucks include mechanical types, vacuum types, and electrostatic types. Electrostatic chucks are particularly useful in the processes which produce semiconductor devices, however, because they can be used under vacuum conditions, do not need mechanical structure to hold the wafer, and can apply a uniform clamping forc .

Two general types of electrostatic chucks are known. In the first type, an electrode is positioned on a support base. An insulator is placed over the electrode and, in turn, the wafer is placed over the insulator. Voltage is applied betw en the electrode and the wafer, creating an lectrostatic force of attraction. Because the voltage is applied between the wafer and the electrode, lectrical contact with the wafer is required. That requirement limits the material to be held, the wafer, to conductors, semiconductors, or materials at least covered with a conductive material on the surface. Thus, semiconductor wafers covered with an insulator such as an SiO_2 film cannot be clamped using the single electrode type of electrostatic chuck.

The second type of electrostatic chuck includes an electrode split into two or more areas, or separate electrodes, which can be held at different potentials. The electrodes, typically planar, are positioned on a support base with a covering insulator and the wafer is placed on the insulator. Voltage is applied between the electrodes, generating a strong electric field which produces an attractive force even if the wafer is coated with an insulator; the wafer is always at a different potential with respect to some part of the split electrodes, regardless of what potential it may assume. Moreover, because the wafer is usually conductive, electrostatic capacities often exist between the wafer and the electrodes.

When the electrode is split into two or more surfaces, problems arise. The force of attraction is very sensitive to small deviations, on the order of a few microns, from the ideal, co-planar position of the surfaces--as well as to surface roughness and flatness in general. It is difficult to isolate the split electrode surfaces electrically yet maintain those surfaces in a flat, co-planar relationship.

Further, in practice, the electrostatic chuck may be part of an rf discharge apparatus. High frequency voltage (rf) is typically supplied through the support and electrode on which the wafer rests. Thus, an rf current flows through the support and electrode to ground or from an rf generator into the discharge through the support and electrode. That rf current may generate different rf potential drops across the support and electrode if the capacitive coupling between the two or more isolated parts of the electrode is too low.

With the above discussion in mind, it is one object of the present invention to provide a split electrode electrostatic chuck having a geometrical design which improves the strength and uniformity of the clamping force of attraction between the chuck and wafer. A second object is to assure that the surface of the split electrode is substantially a single, co-planar, flat, smooth surface. Also of advantage, and a further object, is a maximum thermal contact between the wafer and support.

Still another object of the present invention is to provide a high capacitance between the separate parts of the split electrode to minimize rf voltage drops. Another object is to assure the integrity of the insulator coating of the chuck during manufac-

of 62.5 millimeters, then the nominal wafer overhang is 2.18 millimeters.

Moreover, a protective ring **30**, which may be an anodized aluminum part, surrounds rim **12b** of first electrode **12** of chuck **10**. By assuring that the wafer will always cover surface **26** of chuck **10** and by providing protective ring **30**, the design of the present invention protects insulator **28** from the harmful effects of the processing treatment applied to the wafer. For example, in a plasma etch, the plasma is prevented from accessing insulator **28**. The gap between the wafer overhang and ring **30** must be less than some critical dimension to insure protection. In the embodiment of Fig. 1, that dimension is about 0.25 millimeters.

In order to join first electrode **12** and second electrode **14** and form split-ring electrostatic chuck **10**, a bond between the two electrodes must be created. The integrity of that bond is critical; chuck **10** must present substantially a single, co-planar, flat, smooth surface **26**. The present invention uses an epoxy **32** to form a bond between first electrode **12** and second electrode **14** and to prevent movement and provide sealing.

First electrode **12** has a tapered depression **34** designed to accept band **36** of second electrode **14**. Depression **34** is tapered at an angle, α, of about ten degrees from normal (see Fig. 6). Band **36** is similarly tapered at an angle, β, of about ten degrees from normal (see Fig. 8). By correspondingly tapering depression **34** and band **36**, excess epoxy **32** can be applied and squeezed out during bonding assembly. This leaves a very thin, void-free epoxy joint.

In many known designs, the electrode or electrodes are placed on a support. In chuck **10** of the present invention, first electrode **12** is formed from a single, conducting block which also functions as a support for second electrode **14**, insulator **28**, and the wafer. An additional, separate support **44** is provided to support first electrode **12** and to close the cooling channels **42** (see Fig. 4) formed in first electrode **12**. As shown in Fig. 2, support **44** may be formed integrally with protective ring **30**.

Processing treatments often generate thermal energy in the wafer, which must be dissipated. The design of chuck **10** outlined above assures maximum thermal contact between the wafer and electrodes **12** and **14**, which act as a support for the wafer. By controlling the temperature of electrodes **12** and **14**, the amount of heat exchanged between the wafer and electrodes **12** and **14** can also be controlled. Such temperature control is provided by two, separate systems.

First, as shown in Figs. 3 and 4, chuck **10** has a network of gas distribution grooves **38** throughout both first electrode **12** and second electrode **14**. A gas supply tube **40** is provided vertically through both first electrode **12** and second electrode **14** to connect grooves **38**. A cooling gas, such as Helium, is passed through tube **40** into grooves **38** to transfer heat from the wafer to first electrode **12** and second electrode **14**.

Second, first electrode **12** of chuck **10** has a series of cooling channels **42**. A fluid such as water can be supplied to channels **42**, further cooling first electrode **12** and second electrode **14** and, in turn, dissipating the thermal energy generated in the wafer by the processing treatment.

First electrode **12** and second electrode **14** are held, during operation, at different potentials. As shown in Fig. 2, a first electrical contact **46** is provided to first electrode **12** and a second electrical contact **48** is provided through clearance hole **49** to second electrode **14**. Typically, first electrical contact **46** is a bolt which engages threaded aperture **47** (see Fig. 4). Typically, second electrical contact **48** is a partially threaded metal rod which engages a threaded aperture in second electrode **14**. Voltage is applied between the electrodes, generating a strong electric field which produces an attractive force clamping the wafer to surface **26** of chuck **10**.

Electrical connection may also be made to first electrode **12** by providing a threaded hole in ring **30** for an electrical contact. Typically, the mounting bolts for chuck **10** act as the electrical connection to first electrode **12**. Second electrical contact **48** for second electrode **14** may be an electrically isolated through-hole (not shown) in ring **30** through which contact **48** passes. The diameter of the through-hole should exceed the diameter of the tapped hole in second electrode **14** to prevent surface leakage or breakdown. Note that no electrical contact to the wafer is necessary.

The design of chuck **10** outlined above also assures high capacitance between first electrode **12** and second electrode **14**. Such high capacitance is achieved because the electrodes are in close proximity at both their horizontal and tapered interfaces. It is desirable because the capacitance must be sufficiently great to render negligible the induced rf voltage difference during operation. For the embodiment of chuck **10** shown in Fig. 1, a capacitance in excess of 2,000 pf is acceptable for many applications. When the expected rf current flow is five amperes (40.6 MHz), that capacitance creates an rf voltage difference of 10 volts--which is tolerable. The required capacitance may be more or less, however, depending upon the application and the frequency.

Chuck **10** described above can be manufactured as follows. First electrode **12** is made from a single, conducting block. Similarly, second lectrode **14** is made from a single, conducting block. The thickness of both first electrode **12** and second

first electrode (12); and

a second electrical contact (48) connected to said second electrode (14), wherein a voltage is applied between said first electrode and said second electrode generating an attractive force for clamping a wafer to said clamping surface (26).

2. A split-ring electrostatic chuck as claimed in claim 1 wherein the depression (34) formed between said raised hub (12a) and said raised rim (12b) of said first electrode (12) has a taper of about ten degrees from normal.

3. A split-ring electrostatic chuck as claimed in claim 2 wherein said second electrode has a band (36) formed between said circular wall (16) defining said central opening (18) and said outer edge (24), said band (36) being tapered to correspond to said taper of said depression (34) of said first electrode (12), whereby said band engages said depression.

4. A split-ring electrostatic chuck as claimed in claim 1 wherein said clamping surface (26) defines two, separate, equal electrode areas.

5. A split-ring electrostatic chuck as claimed in claim 4 wherein said equal electrode areas are symmetrically distributed.

6. A split-ring electrostatic chuck as claimed in claim 1 wherein said clamping surface (26) is a single, co-planar, flat, smooth surface.

7. A split-ring electrostatic chuck as claimed in claim 1 wherein the outer boundary of the semiconductor wafer clamped by said electrostatic chuck on said clamping surface (26) extends beyond the outer boundary of said clamping surface.

8. A split-ring electrostatic chuck as claimed in claim 1 further comprising a protective ring (30) surrounding said rim (12b) of said first electrode (12) of said electrostatic chuck.

9. A split-ring electrostatic chuck as claimed in claim 8 wherein said protective ring (30) is anodized aluminum.

10. A split-ring electrostatic chuck as claimed in claim 1 wherein an epoxy bond (32) is formed between said first electrode (12) and said second electrode (14).

11. A split-ring electrostatic chuck as claimed in claim 1 wherein no electrical contact is made to said wafer.

12. A split-ring electrostatic chuck as claimed in claim 1 wherein a capacitance is generated between said first electrode (12) and said second electrode (14), said capacitance being sufficiently great to render negligible the induced rf voltage difference.

13. A split-ring electrostatic chuck as claimed in claim 1 wherein said electrostatic chuck has a network of gas distribution grooves (38) through said first electrode (12) and said second electrode (14) and a vertically disposed gas supply tube (40) through said first electrode and said second electrode connecting said grooves.

14. A split-ring electrostatic chuck as claimed in claim 13 wherein a cooling gas is passed through said gas supply tube (40) into said network of gas distribution grooves (38) to control the temperature of the semiconductor wafer clamped by said electrostatic chuck on said clamping surface (26).

15. A split-ring electrostatic chuck as claimed in claim 1 wherein said first electrode (12) has a series of cooling channels (42) for carrying a fluid.

16. A split-ring electrostatic chuck as claimed in claim 1 wherein said insulator (28) has a thickness of between approximately 0.025 and 0.08 mm (0.001 and 0.003 inches).

17. A split-ring electrostatic chuck as claimed in claim 16 wherein said insulator (28) has a breakdown voltage strength of at least 20 Volts per μm (500 volts per mil).

18. A split-ring electrostatic chuck as claimed in claim 16 wherein said insulator (28) is anodized aluminum.

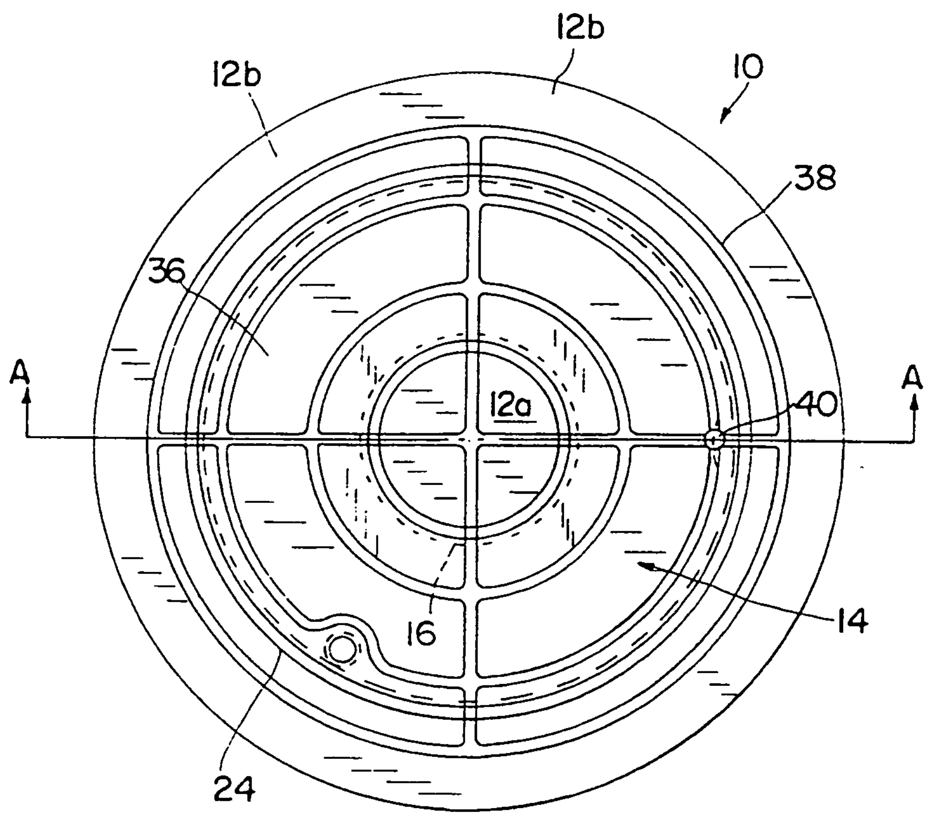
12b
12b
10
38
36
A
12a
40
A
16
14
24

FIG.3

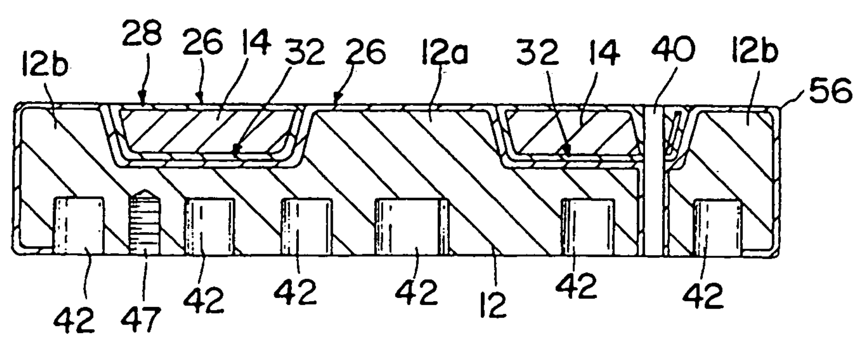
28
26
14
32
26
12a
32
14
40
12b
12b
56
42
47
42
42
42
12
42
42

FIG.4

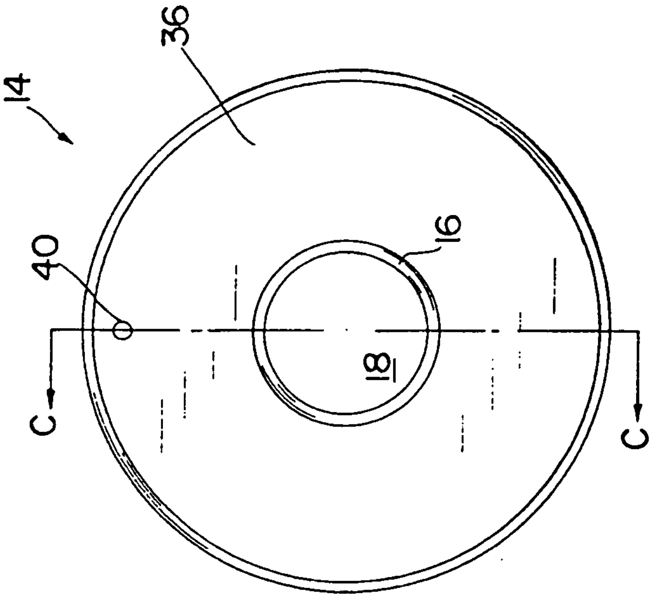

FIG.7

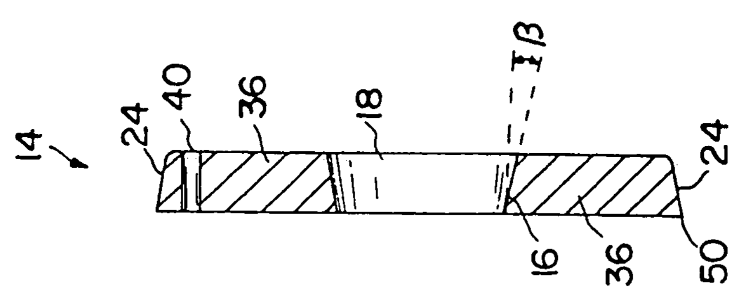

FIG.8